Planet Dove Constellation Absolute Geolocation Accuracy, Geolocation Consistency, and Band Co-Registration Analysis

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NATIONAL GEOSPATIAL NGA INTELLIGENCE AGENCY

Planet Dove Constellation

Planet (formerly Planet Labs)

- Launched 220+ Dove smallsats
- ~145 currently in orbit
- Later versions carry PlanetScope 2 (PS2) sensor
- 3- to 5-meter ground sample distance (GSD) depending on orbital altitude

NIQU obtained test PS2 imagery through the Planet Feed contract awarded in September 2016

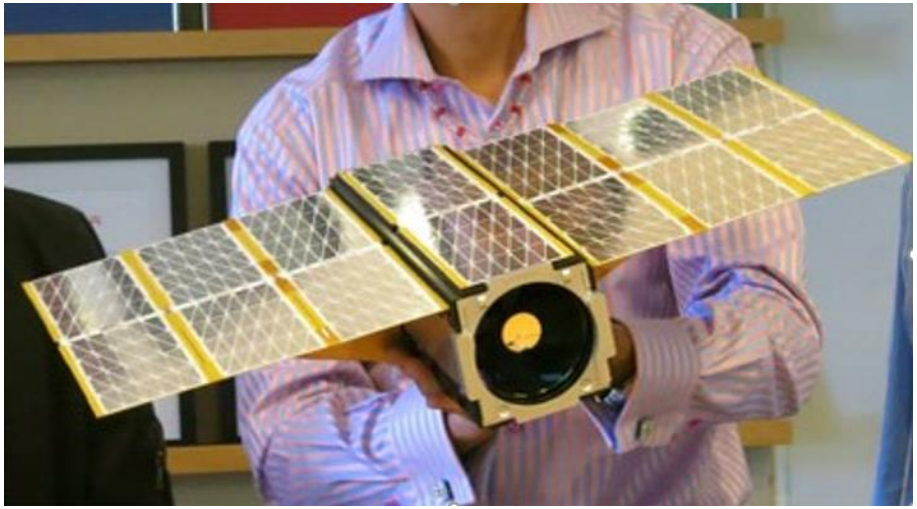

Photo approved for public release, 13-153

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Assessments Performed

Absolute Geolocation Accuracy

- Question: How accurate is the geolocation?
- Approach: Compare coordinates derived from test imagery to known ground points

Geolocation Consistency

- Question: What is the geo-registration consistency of a time series of images over the same location?
- Approach: Compare coordinates of common points on overlapping images

Band Co-Registration Analysis

- Question: How well are spectral bands co-registered?
- Approach: Compare each band to one another using the phase correlation technique

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Absolute Geolocation Accuracy Assessment

Test Data: 60 unrectified (Basic) Dove PS2 images

- Over Terminal Aeronautical Global Navigation Satellite System (GNSS) Geodetic Surveys (TAGGS) test sites
- Each product includes Rational Polynomial Coefficient (RPC) text file for geolocation
- Collected: 14 July 2016 – 10 January 2017
- Geo-registration processing: 21 December 2016 – 10 January 2017

Test Process

- Used SOCET GXP to determine horizontal coordinates at each ground-surveyed height using mono intersection (diagram on next slide)
  - On each image, measured latitude and longitude of each checkpoint at truth height
  - For each measured point on an image, calculated the delta between the measured and true latitude and longitude coordinates (horizontal error for point)
  - For each image, compute a representative horizontal error using Equation 5.6.4.1-1 in NGA.SIG.0026.05_1.0_ACCSPEC
  - Used representative horizontal errors as samples to estimate CE90 and confidence intervals using ordered statistics per Appendix C in NGA.SIG.0026.04_1.0_ACCSAMP

Planet Geolocation Accuracy Specification

- 10-meter root mean square error (RMSE) → 15.2-meter CE90 using circular normal assumptions per Appendix I, NGA.SIG.0026.05_1.0_ACCSPEC

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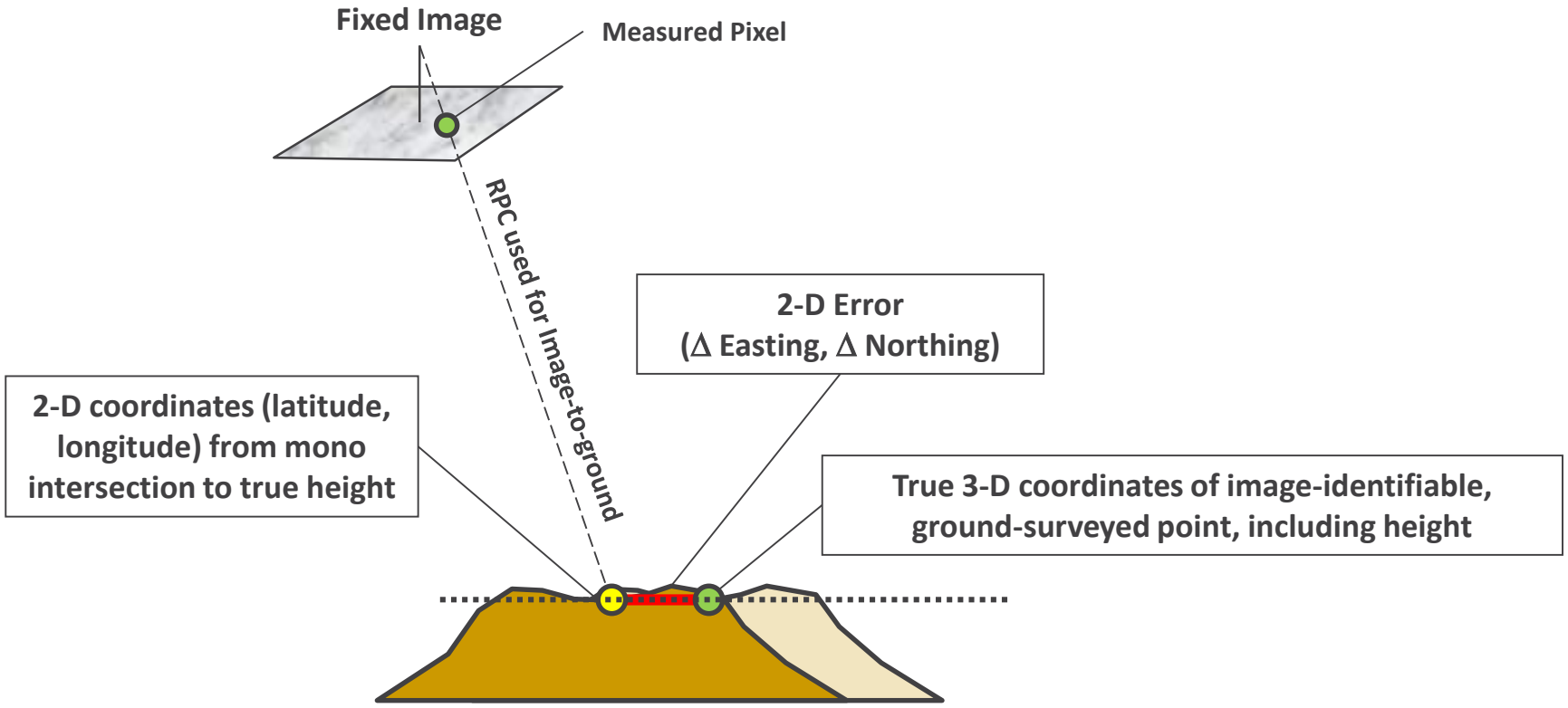
Mono Intersection for Unrectified Products



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Absolute Geolocation Accuracy: All Basic 60 Images

Case	Rep_Hor_Error (m)	Case	Rep_Hor_Error (m)
OM_Masirah Island-20161229_0c81	1.6	IT_Sigonella-20170107_0c78	4.5
UZ_K Khanabad-20161220_0e1f	1.9	SK_Kosice-20161216_0c60	4.5
MD_Balti-20160827_0c43	2.0	MG_Antananarivo-20170108_0e20	4.9
GY_Cheddi Jagan-20161016_0c81	2.1	PH_Zamboanga-20161130_0e30	5.0
CW_Hato-20161113_0e20	2.2	IQ_Al_Sahra-20170107_0e0d	5.2
SR_Johan Pengel-20161128_0c41	2.2	GT_Puerto Barrios-20161229_0c76	5.3
US_Allen-20160727_0e3a	2.2	GW_Osvaldo Vieira-20170102_0e2f	5.3
BS_Nassau-20161208_0e26	2.4	CL_Carlos Ibanez-20161126_0e20	5.4
AF_Chagcharan-20161229_0e2f	2.5	US_McChord-20170106_0e0e	5.5
ET_Gode-20170103_0c75	2.8	DE_Nordholz-20161128_0e19	5.5
TR_Incirlik-20161231_0c75	2.9	PA_Caazapa-20170109_0e26	5.5
JP_Kadena-20160714_0c2b	3.0	IQ_Al_Asad-20161202_0e30	5.7
BA_Sarajevo-20161025_0c37	3.1	TT_Piarco-20161205_0c38	6.1
VI_Cyril E King-20161125_0e30	3.1	KR_A511-20161228_0e1f	6.4
ES_Rota-20161230_0c0b	3.1	TN_Carthage-20161226_0e0d	6.6
PH_Baguio-20170109_0e0e	3.2	PE_Jose Gonzales-20170103_0e3a	6.8
CU_Guantanamo Bay-20170103_0e26	3.3	PK_Shabaz-20161230_0e2f	6.8
US_San Clemente-20161229_0e0d	3.3	MA_Sidi Slimane-20170105_0c82	7.7
BO_JW-20170101_0e0e_PLFD	3.3	AR_Cataratas-20170109_0e3a	7.8
UY_Carrasco-20161229_0c37	3.4	GM_Banjul-20161106_0c19	7.9
US_AC Perkinson_20161110_0c75	3.5	GR_Souda Bay-20161112_0e14	9.6
PH_Bacolod-20161109_0e14	3.5	MV_Male-20161226_0e3a	12.1
LK_Ratmalana -20170104_0c82	3.5	PE_Rod Ballon-20161213_0d06	12.3
CL_Arturo Merino-20170105_0c75	3.6	KG_Manas-20160831_0e3a	15.5
NA_Walvis Bay-20160912_0c78	3.6	SN_Leo Senghor-20170102_0c81	19.0
US_Tinker-20161231_0c42	3.8	MH_Bucholz-20161021_0c76	29.4
EC_Mariscal Lamar-20161117_0e14	3.8	KE_Jomo Kenyatta-20170108_0e16	32.6
HN_Enrique Soto-20161211_0e0e	3.9	MH_Dyess-20161109_0c24	34.7
AG_VC_Bird-20170106_0e26	4.0	GU_Andersen-20161116_0e0d	48.0
JP_Atsugi-20170110_0e20	4.1	EC_Seymour-20161031_0e30	336.4

Geo-Registration Processing: 21 December 2016 – 10 January 2017

CE90 is estimated at 54th position out of 60

- 15.5 meters (red box)
- (Specification: 15.2 meters)

Two-sided 90 percent confidence interval range from 50th to 58th positions

- 7.9 to 34.7 meters (green box)

Least Upper Bound (LUB) at 58th position

- There is at least a 93.3 percent certainty that the true CE90 is less than 34.7 meters (orange box)

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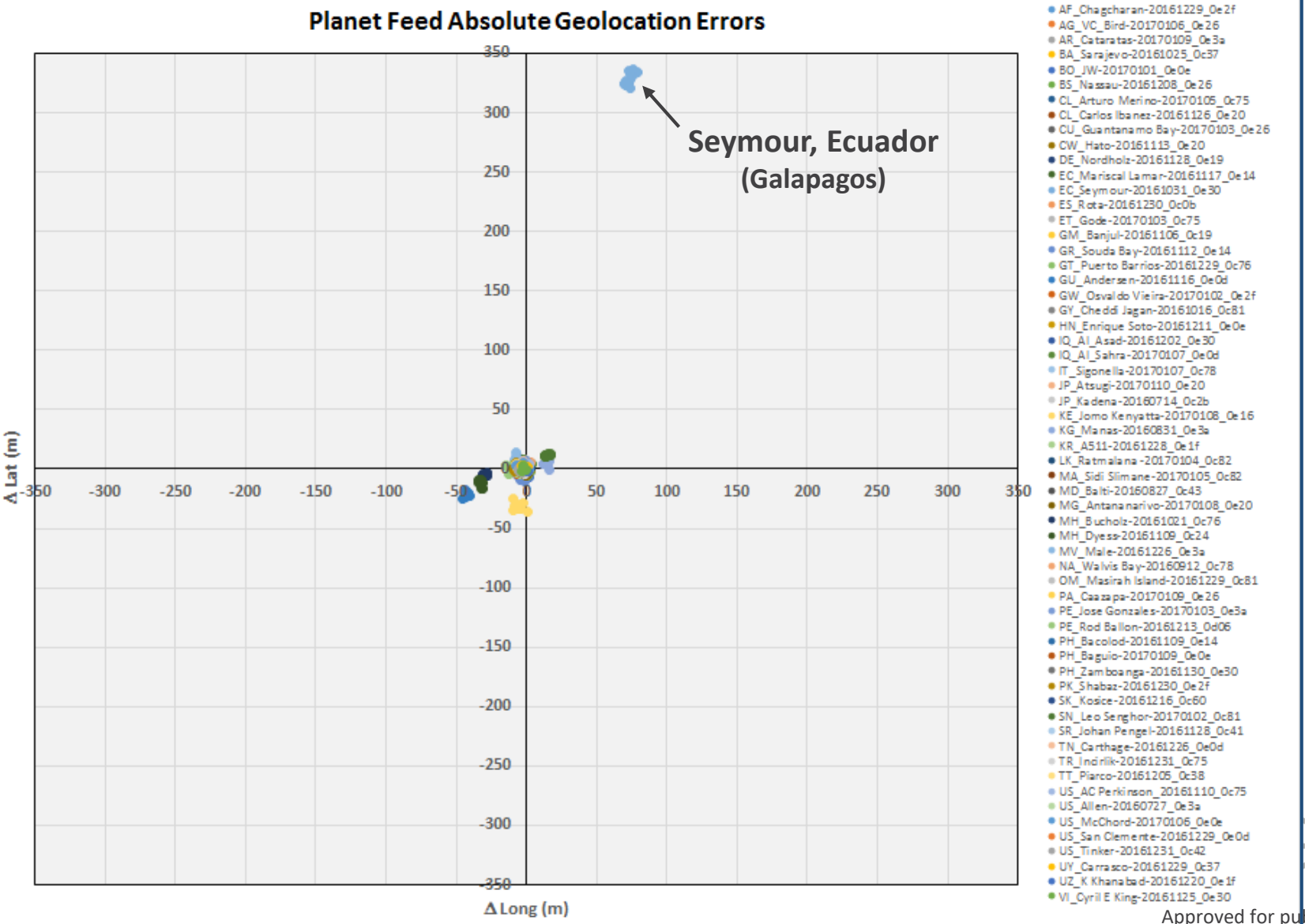
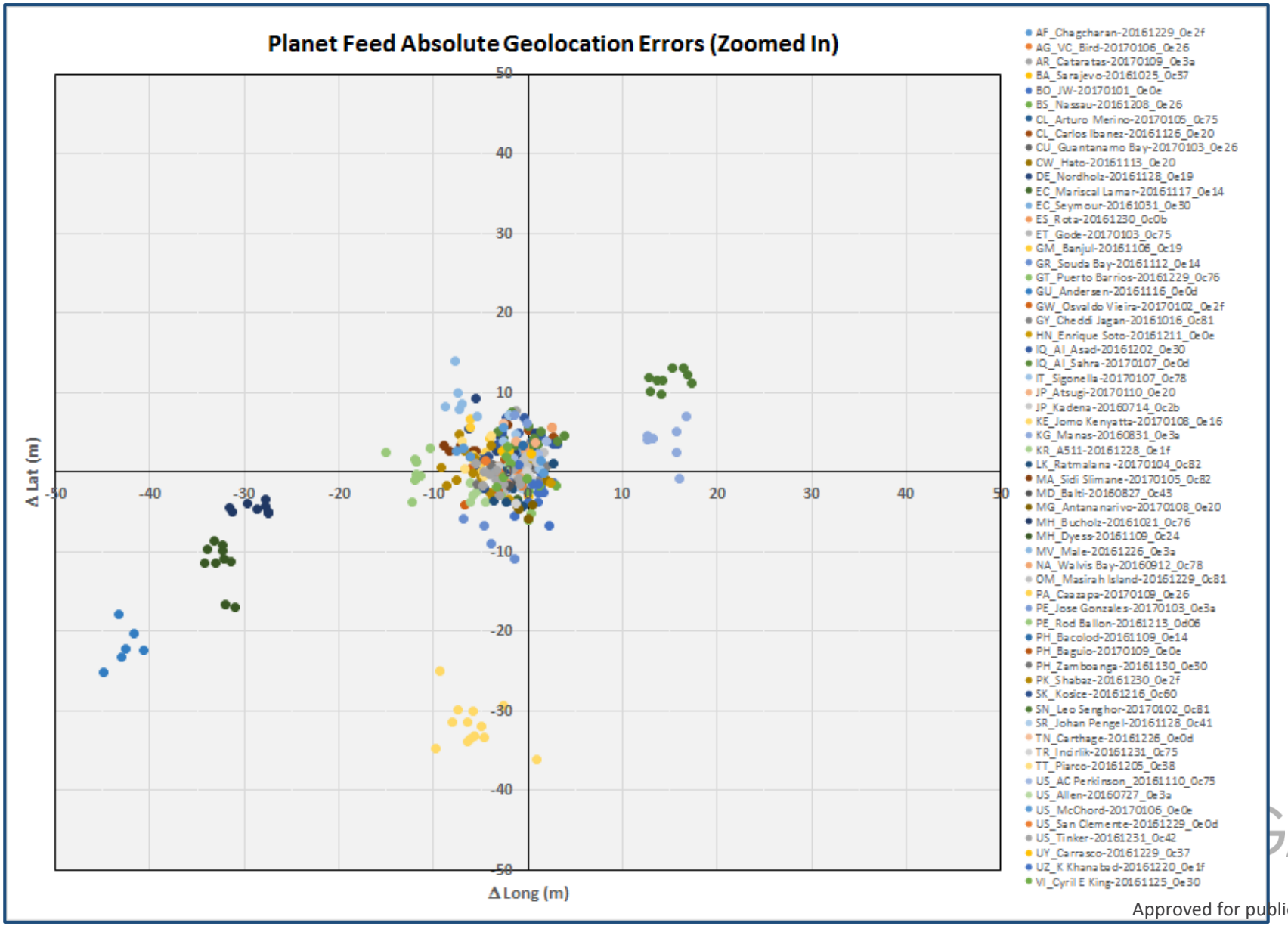
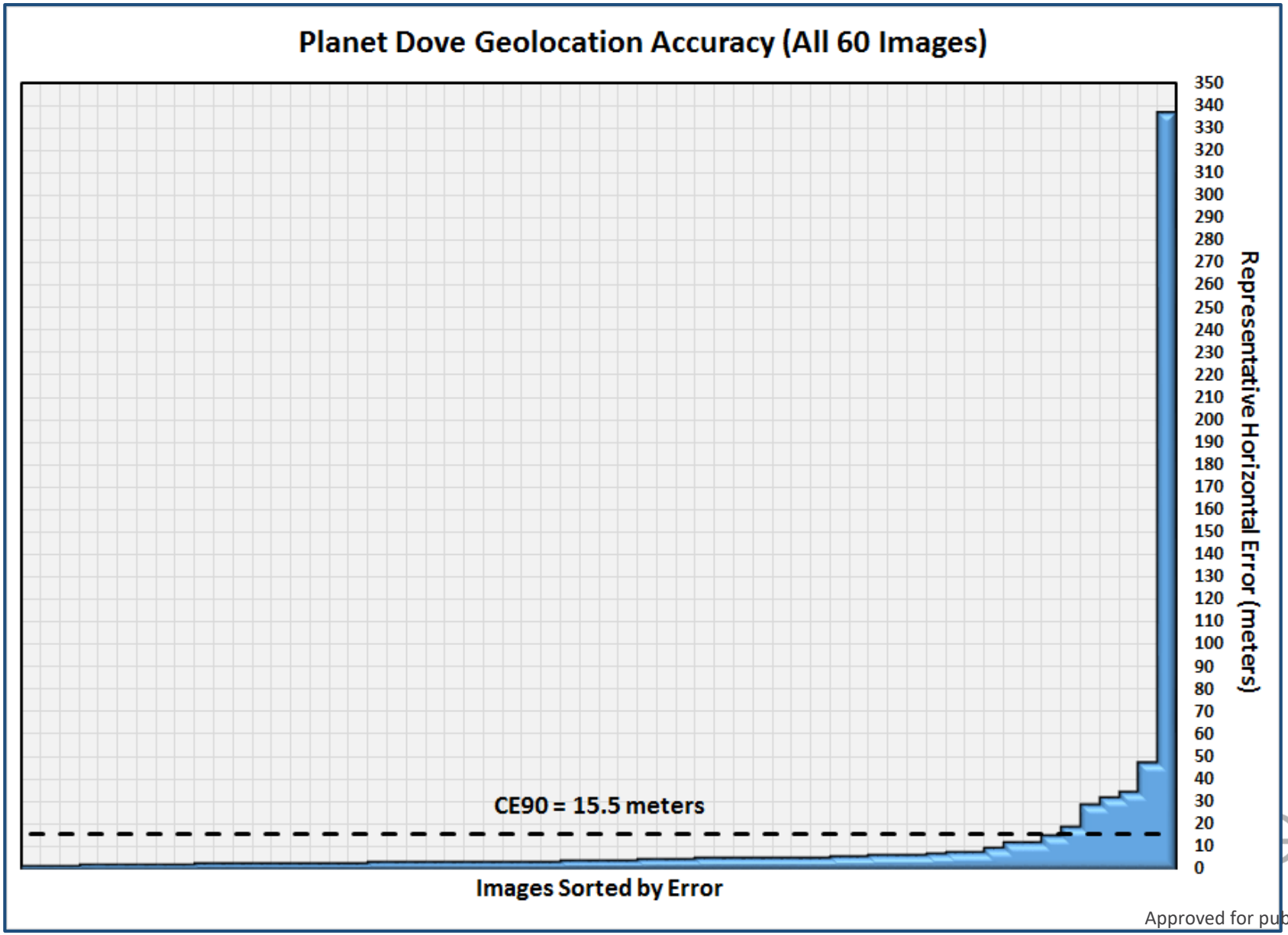
Absolute Geolocation Accuracy: Scatterplot of All Points for All 60 Images



Absolute Geolocation Accuracy: Scatterplot of Points for 59 Images (Zoomed In)



Absolute Geolocation Accuracy: Images Sorted by Error



Absolute Geolocation Accuracy: Results for 48 Images (Without Small Islands)

Case	Rep_Hor_Error (m)	Case	Rep_Hor_Error (m)
UZ_K Khanabad-20161220_0e1f	1.9	IT_Sigonella-20170107_0c78	4.5
MD_Balti-20160827_0c43	2.0	SK_Kosice-20161216_0c60	4.5
GY_Cheddi Jagan-20161016_0c81	2.1	MG_Antananarivo-20170108_0e20	4.9
SR_Johan Pengel-20161128_0c41	2.2	PH_Zamboanga-20161130_0e30	5.0
US_Allen-20160727_0e3a	2.2	IQ_Al_Sahra-20170107_0e0d	5.2
AF_Chagcharan-20161229_0e2f	2.5	GT_Puerto Barrios-20161229_0c76	5.3
ET_Gode-20170103_0c75	2.8	GW_Osvaldo Vieira-20170102_0e2f	5.3
TR_Incirlik-20161231_0c75	2.9	CL_Carlos Ibanez-20161126_0e20	5.4
JP_Kadena-20160714_0c2b	3.0	US_McChord-20170106_0e0e	5.5
BA_Sarajevo-20161025_0c37	3.1	DE_Nordholz-20161128_0e19	5.5
ES_Rota-20161230_0c0b	3.1	PA_Caazapa-20170109_0e26	5.5
PH_Baguio-20170109_0e0e	3.2	IQ_Al_Asad-20161202_0e30	5.7
CU_Guantanamo Bay-20170103_0e26	3.3	KR_A511-20161228_0e1f	6.4
BO_JW-20170101_0e0e_PLFD	3.3	TN_Carthage-20161226_0e0d	6.6
UY_Carrasco-20161229_0c37	3.4	PE_Jose Gonzales-20170103_0e3a	6.8
US_AC Perkinson_20161110_0c75	3.5	PK_Shabaz-20161230_0e2f	6.8
PH_Bacolod-20161109_0e14	3.5	MA_Sidi Slimane-20170105_0c82	7.7
LK_Ratmalana -20170104_0c82	3.5	AR_Cataratas-20170109_0e3a	7.8
CL_Arturo Merino-20170105_0c75	3.6	GM_Banjul-20161106_0c19	7.9
NA_Walvis Bay-20160912_0c78	3.6	GR_Souda Bay-20161112_0e14	9.6
US_Tinker-20161231_0c42	3.8	PE_Rod Ballon-20161213_0d06	12.3
EC_Mariscal Lamar-20161117_0e14	3.8	KG_Manas-20160831_0e3a	15.5
HN_Enrique Soto-20161211_0e0e	3.9	SN_Leo Senghor-20170102_0c81	19.0
JP_Atsugi-20170110_0e20	4.1	KE_Jomo Kenyatta-20170108_0e16	32.6

CE90 is estimated at midpoint between the 44th and 45th position out of 48

- 11.0 meters (red box)
- (Specification is 15.2 meters)

Two-sided 94.7 percent confidence interval range from 40th to 48th positions

- 6.8 to 32.6 meters (green box)

LUB at 47th position

- There is at least a 95.9 percent certainty that the true CE90 is less than 19.0 meters (orange box)

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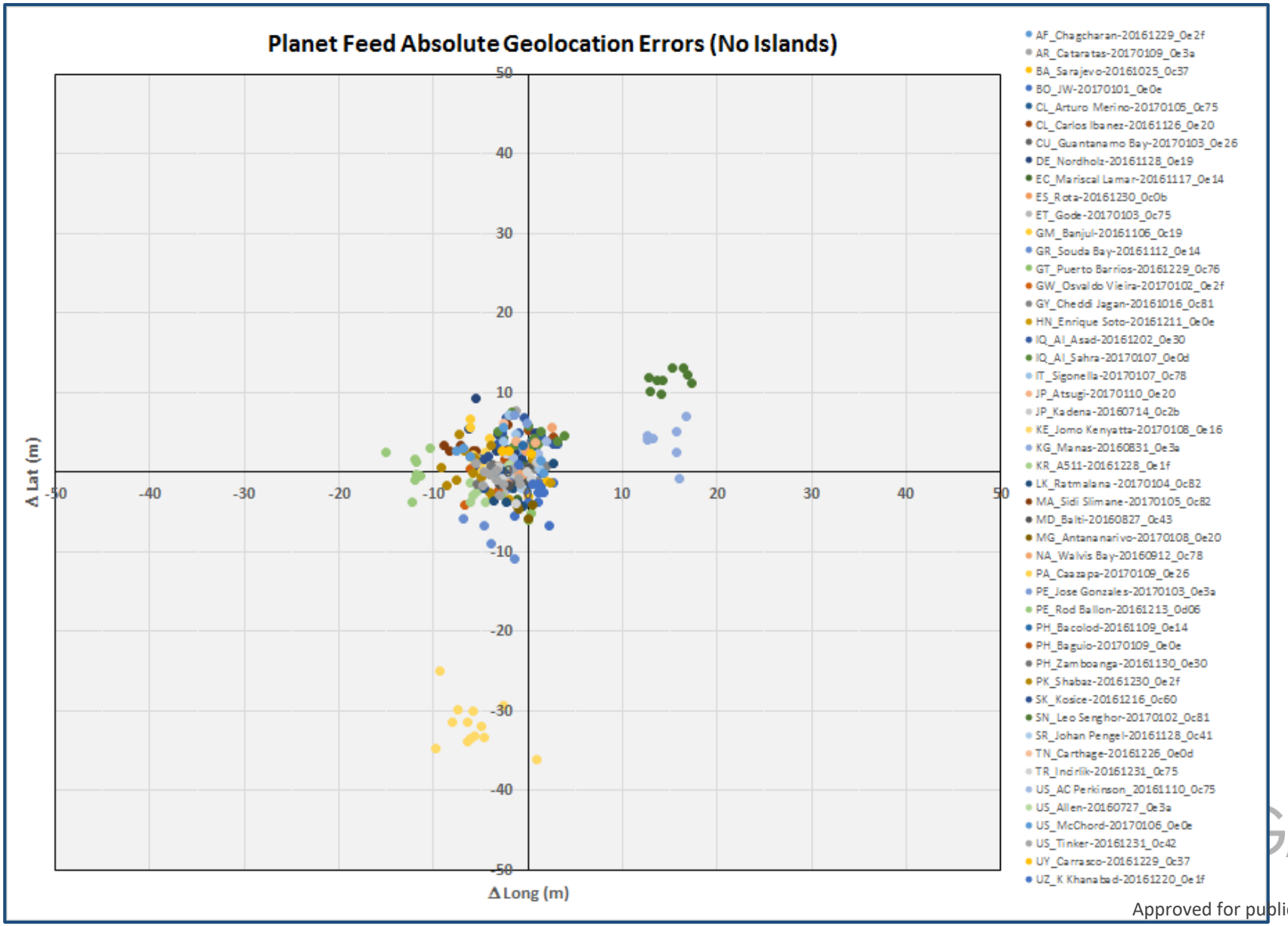
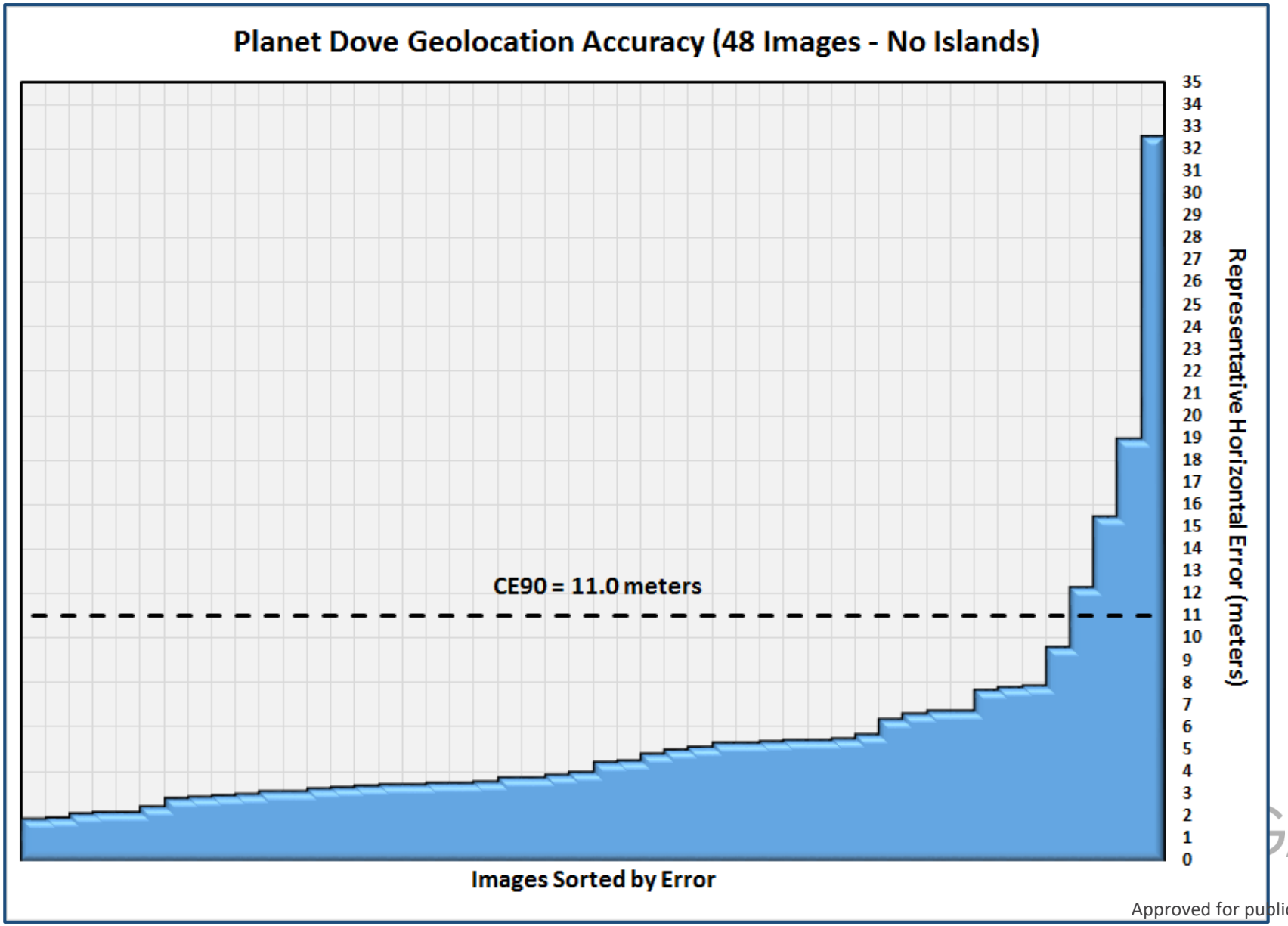
Absolute Geolocation Accuracy: Scatterplot (48 Images – No Small Islands)



Absolute Geolocation Accuracy: Images Sorted by Error (48 Images – No Small Islands)



Absolute Geolocation Accuracy: Conclusions

Absolute geolocation accuracy is influenced by Planet processing CONOPS to register PS2 images to reference image layers of varying sources and accuracy

- TAGGS sites chosen to be distributed around the Earth as much as possible to form a representative global sampling
- Geo-registration processing: 21 December 2016 – 10 January 2017
- For this data, small islands tend to have larger errors
  - CE90 estimate meets specification when small islands are removed

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Geolocation Consistency Assessment

Objective:

- Determine the consistency in geo-registration of time series of PS2 images over a specific location

Test Process:

- Identify test sites with multiple, different-day collects of PS2 images
- Compare geolocation of geo-registered images for each test site
- Repeatability is indicated by similar geo-registration

Test Data: (next slide)

Significance: If non-repeatable geo-registration occurs, the following will result:

- Visual misalignment of image and data overlays
- Automated analytic algorithm may fail due to misaligned pixels
- Misalignment tolerance depends upon application

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Test Data

Stacks of Orthorectified Analytic Products Over Five Test Locations

Test Location	Product	# of Images	Published/Updated
Washington, DC, US	Ortho Tile	10	9 December 2016 – 9 January 2017
Near Agra, India	Ortho Tile	10	
Near Nairobi, Kenya	Ortho Scene	11	25 August 2016 – 26 January 2017
Near Sao Paulo, Brazil	Ortho Scene	6	
Near Beijing, China	Ortho Scene	6	

Images Collected: 24 August 2016 – 25 January 2017

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Methodology

Used the Triangulation Tool in SOCET GXP

- Tool usually used to adjust images to ground control points
- Instead, NIQU used the tool to allow ground points to move to un-adjusted Planet Orthos
  - Ground points were allowed to adjust, but Planet Orthos were prevented from adjusting

Measured points on stacks of images

- Distinct points manually measured on at least two images, depending on overlap
- Points densified and dispersed to cover overlap areas
- Cross-checked among three analysts to avoid identification errors and to minimize pixel measurement errors

Used the ground coordinate differencing tool (Quality Statistics Report) in SOCET GXP to calculate the delta between the ground coordinates of points of each image pair

- For example, a 10-image stack results in 45 image pair comparisons for that stack
- For each image pair comparison, NIQU computed a representative horizontal coordinate delta from the points common to the image pair using Equation 5.6.4.1-1 in NGA.SIG.0026.05_1.0_ACCSPEC

Analyzed image pair deltas within and among stacks

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Number of Image Pairs and Points for Each Test Location

Test Location	Product	# of Images	# of Image Pairs	# of Points Per Pair
Washington, DC, US	Ortho Tile	10	45	33 to 76
Near Agra, India	Ortho Tile	10	45	8 to 45
Near Nairobi, Kenya	Ortho Scene	11	55	2 to 40
Near Sao Paulo, Brazil	Ortho Scene	6	15	9 to 31
Near Beijing, China	Ortho Scene	6	15	15 to 35

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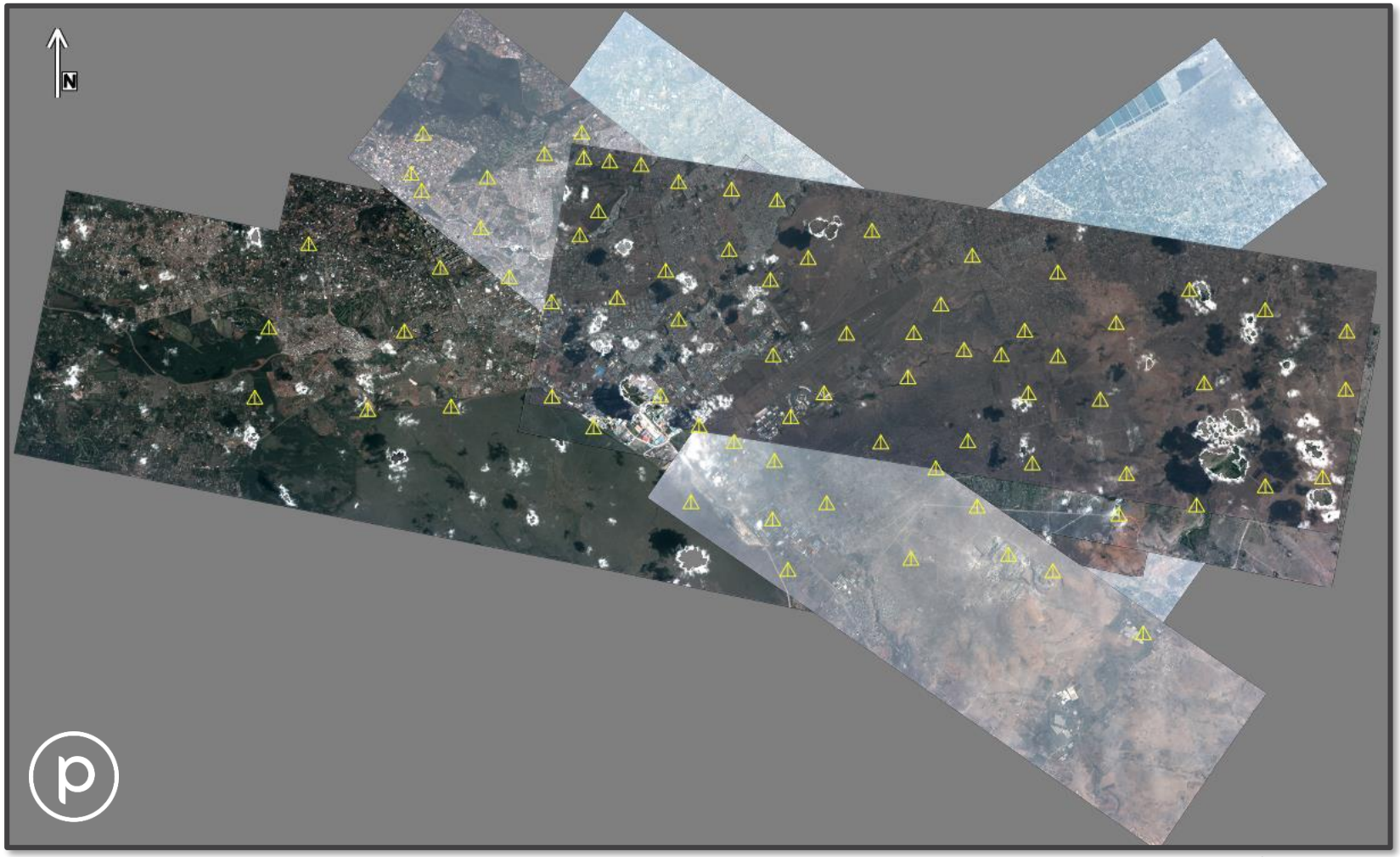
Example: Overlap and Point Distribution Near Nairobi, Kenya



Representative Horizontal Coordinate Differences Between Image Pairs

Washington, DC, US

Image ID	241239_1857007_2016-09-14_0c27	267891_1857007_2016-10-14_0e3a	272538_1857007_2016-10-20_0c76	277614_1857007_2016-10-26_0c24	280153_1857007_2016-10-29_0e3a	288128_1857007_2016-11-08_0e3a	291971_1857007_2016-11-13_0e3a	316918_1857007_2016-12-01_0e19	328279_1857007_2016-12-15_0c46	Image ID
5.9	3.4	5.5	8.4	4.7	4.8	4.5	5.5	7.3		227706_1857007_2016-08-24_0e0f
	6.8	8.7	10.2	7.6	7.0	6.4	8.3	11.3		241239_1857007_2016-09-14_0c27
		5.1	8.4	3.3	3.4	3.8	5.1	5.8		267891_1857007_2016-10-14_0e3a
			10.9	6.6	5.8	2.7	8.0	7.8		272538_1857007_2016-10-20_0c76
				9.3	8.0	8.7	8.9	10.9		277614_1857007_2016-10-26_0c24
					2.3	2.3	4.5	5.8		280153_1857007_2016-10-29_0e3a
						2.0	3.3	5.3		288128_1857007_2016-11-08_0e3a
							2.8	5.7		291971_1857007_2016-11-13_0e3a
								6.5		316918_1857007_2016-12-01_0e19

Representative Horizontal Differences (in meters)

Median = 5.8 meters

Near Agra, India

Image ID	234841_4451602_2016-09-07_0e0f	239333_4351627_2016-09-12_0e3a	263895_4451602_2016-10-09_0e14	266615_4351627_2016-10-13_0e0f	267659_4451602_2016-10-14_0c43	274831_4351627_2016-10-23_0c19	277288_4451602_2016-10-26_0d06	282934_4351627_2016-11-02_0c75	283805_4451602_2016-11-03_0c24	Image ID
5.5	6.5	15.5	14.7	15.2	12.1	4.0	4.2	4.7		302343_4351627_2016-11-23_0e1f
	5.9	15.4	13.4	14.5	12.8	5.2	5.0	5.0		234841_4451602_2016-09-07_0e0f
		13.0	17.1	11.9	13.7	7.9	6.6	6.3		239333_4351627_2016-09-12_0e3a
			14.1	3.5	6.2	16.4	15.7	15.2		263895_4451602_2016-10-09_0e14
				12.8	12.9	15.1	13.7	14.0		266615_4351627_2016-10-13_0e0f
					3.9	15.8	14.9	14.8		267659_4451602_2016-10-14_0c43
						14.9	14.4	13.5		274831_4351627_2016-10-23_0c19
							4.0	4.3		277288_4451602_2016-10-26_0d06
								3.7		282934_4351627_2016-11-02_0c75

Representative Horizontal Differences (in meters)

Median = 12.9 meters

Maximum Difference

Minimum Difference

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Representative Horizontal Coordinate Differences Between Image Pairs

Near Sao Paulo, Brazil

Image ID	2016-09-23_111622_0c65	2016-12-18_100607_1_0c81	2016-12-25_122847_0e14	2016-10-31_122616_0e19	2016-09-08_122447_0e2f	Image ID
3.2	6.5	5.0	3.9	3.0		2016-08-29_122417_0e20
	5.1	5.2	3.9	3.8		2016-09-23_111622_0c65
		6.8	5.9	5.6		2016-12-18_100607_1_0c81
			2.9	5.5		2016-12-25_122847_0e14
				4.1		2016-10-31_122616_0e19
Representative Horizontal Differences (in meters)						
Median = 5.0 meters						

Near Nairobi, Kenya

Image ID	2016-10-22_044802_1_0c65	2016-12-06_103752_0c24	2016-12-17_070725_0e19	2016-12-18_070757_0e0e	2017-01-08_070901_0e16	2017-01-10_070852_0e20	2017-01-20_044619_0c41	2017-01-24_070922_0e0f	2017-01-25_143349_0c59	20170125_145235_0c62	Image ID
17.1	29.3	25.4	21.2	36.3	40.0	32.1	37.2	28.0	31.1		2016-08-25_070412_0e16
	27.8	21.3	14.3	28.0	31.1	27.4	35.9	33.4	29.7		2016-10-22_044802_1_0c65
		9.4	15.6	8.8	11.0	14.8	8.7	13.0	11.2		2016-12-06_103752_0c24
			16.4	15.7	20.6	9.9	19.6	9.4	11.0		2016-12-17_070725_0e19
				6.9	5.8	20.1	12.5	11.9	8.1		2016-12-18_070757_0e0e
					8.7	15.3	9.2	18.4	16.0		2017-01-08_070901_0e16
						19.7	13.5	22.6	19.7		2017-01-10_070852_0e20
							16.8	8.0	8.9		2017-01-20_044619_0c41
								24.1	17.2		2017-01-24_070922_0e0f
									9.5		2017-01-25_143349_0c59
Representative Horizontal Differences (in meters)											
Median = 16.8 meters											

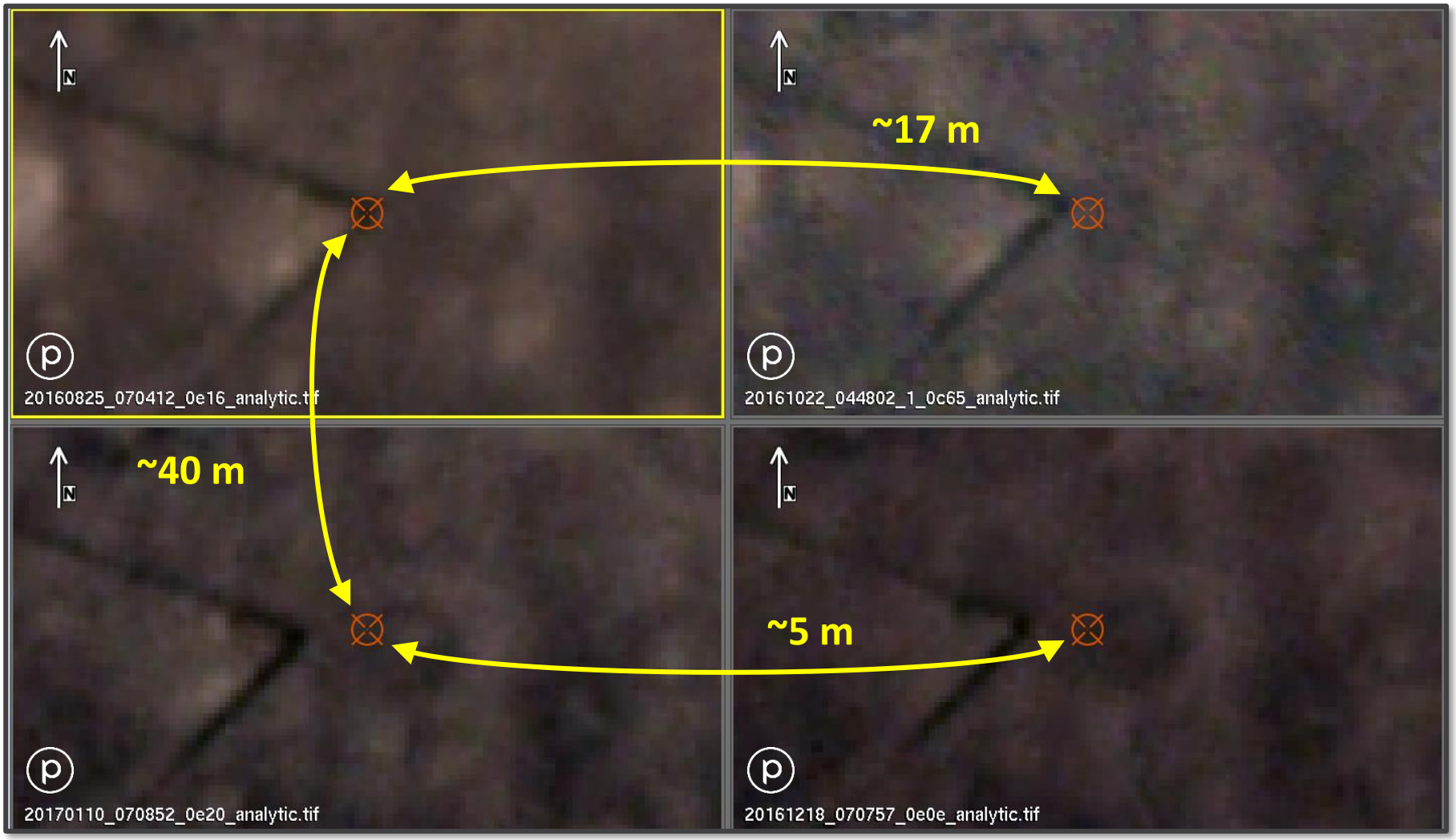
Near Beijing, China

Image ID	2017-01-02_035232_0c13	2016-11-02_042520_0c81	2017-01-14_021553_0e0f	2016-12-29_021525_0e16	2017-01-22_021551_0e3a	Image ID
3.1	0.8	2.0	3.9	2.0		20161031_052552_0c45
	3.4	2.0	2.6	2.2		2017-01-02_035232_0c13
		3.8	2.9	2.8		2016-11-02_042520_0c81
			1.1	1.5		2017-01-14_021553_0e0f
				1.7		2016-12-29_021525_0e16
Representative Horizontal Differences (in meters)						
Median = 2.3 meters						

Maximum Difference

Minimum Difference

Example: Observed Offsets Near Nairobi, Kenya (Four Linked Images)



Red cursor is at same horizontal coordinates in each panel
Refer to corresponding table cells on previous slide

Geolocation Consistency: Summary of Results

Test Location	Product	Representative Horizontal Error		
		Min (m)	Max (m)	Median (m)
Washington, DC, US	Ortho Tile	2.0	11.3	5.8
Near Agra, India	Ortho Tile	3.5	17.1	12.9
Near Nairobi, Kenya	Ortho Scene	5.8	40.0	16.8
Near Sao Paulo, Brazil	Ortho Scene	2.9	6.8	5.0
Near Beijing, China	Ortho Scene	0.8	3.9	2.3

Planet uses a geo-registration process to tie images to underlying reference imagery layer

- If PS2 images are consistently registered to the reference layer, then very small horizontal coordinate differences (e.g., at pixel level) should be observed

This is a small sample size, but is a random sample of five locations spread around the world

- NIQU observed median errors between 0.7 to 5 pixels, with the maximum case being 13 pixels (assuming a typical GSD of 3.125 meters for ortho tiles)
- Geo-registration processing: 25 August 2016 – 26 January 2017

Conclusion: There can be relative geolocation differences between successive images over the same ground area

- Misalignment tolerance depends upon application

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Band Co-Registration Assessment

Objective:

- Assess band co-registration
- Generally, products created for the mathematical manipulation or combination of multiple images or bands require a registration accuracy of better than 0.1 pixels
- Images or bands overlaid for the purpose of visual interpretation generally require a registration accuracy of better than 0.25 pixels

Test Data:

- 10 Planet Basic 4-band (Blue, Green, Red, Near Infrared) images
  - Collected: 27 July 2016 – 10 January 2017
  - Geo-registration processing: 21 December 2016 – 10 January 2017

Test Process:

- NIQU processed each image using a NIQU-developed Band Co-Registration Error tool to determine pixel registration errors between each band using phase correlation techniques
- The results include Band-to-Band Mean Error and Correlation
  - Band 1 to Band 1, Band 1 to Band 2, Band 1 to Band 3, Band 1 to Band 4
  - Band 2 to Band 1, Band 2 to Band 2, Band 2 to Band 3, Band 2 to Band 4
  - Band 3 to Band 1, Band 3 to Band 2, Band 3 to Band 3, Band 3 to Band 4
  - Band 4 to Band 1, Band 4 to Band 2, Band 4 to Band 3, Band 4 to Band 4

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Band Co-Registration: Example Summaries for Two Images

Mean Pixel Error Summary

Ref Band to Match Band File : A511_20161228_013046_0e1f.tif	Mean Reg Error	Std Dev Reg Error	Median Reg Error	Min Reg Error	Max Reg Error	Mean Corr	StdDev Corr	Median Cor Value	Min Cor Value	Max Cor Value
Band1-to-Band1	0	0	0	0	0	1	0	1	1	1
Band1-to-Band2	0.029	0.014	0.029	0.006	0.074	0.785	0.01	0.786	0.763	0.811
Band1-to-Band3	0.024	0.011	0.022	0.005	0.057	0.68	0.012	0.679	0.649	0.711
Band1-to-Band4	0.395	0.144	0.402	0.089	0.745	0.19	0.028	0.193	0.131	0.251
Band2-to-Band1	0.029	0.014	0.029	0.006	0.074	0.785	0.01	0.786	0.763	0.811
Band2-to-Band2	0	0	0	0	0	1	0	1	1	1
Band2-to-Band3	0.016	0.008	0.015	0.004	0.034	0.715	0.012	0.713	0.692	0.739
Band2-to-Band4	0.377	0.141	0.368	0.057	0.719	0.22	0.029	0.218	0.163	0.28
Band3-to-Band1	0.024	0.011	0.022	0.005	0.057	0.68	0.012	0.679	0.649	0.711
Band3-to-Band2	0.016	0.008	0.015	0.004	0.034	0.715	0.012	0.713	0.692	0.739
Band3-to-Band3	0	0	0	0	0	1	0	1	1	1
Band3-to-Band4	0.394	0.141	0.392	0.087	0.685	0.207	0.027	0.209	0.155	0.259
Band4-to-Band1	0.395	0.144	0.402	0.089	0.745	0.19	0.028	0.193	0.131	0.251
Band4-to-Band2	0.377	0.141	0.368	0.057	0.719	0.22	0.029	0.218	0.163	0.28
Band4-to-Band3	0.394	0.141	0.392	0.087	0.685	0.207	0.027	0.209	0.155	0.259
Band4-to-Band4	0	0	0	0	0	1	0	1	1	1

Mean Pixel Error Summary

Ref Band to Match Band File : A P Hill-20161231_150932_0e19.tif	Mean Reg Error	Std Dev Reg Error	Median Reg Error	Min Reg Error	Max Reg Error	Mean Corr	StdDev Corr	Median Cor Value	Min Cor Value	Max Cor Value
Band1-to-Band1	0	0	0	0	0	1	0	1	1	1
Band1-to-Band2	0.023	0.014	0.021	0.003	0.099	0.791	0.01	0.795	0.763	0.804
Band1-to-Band3	0.016	0.01	0.013	0.004	0.04	0.701	0.009	0.702	0.679	0.727
Band1-to-Band4	0.967	0.932	0.685	0.02	3.925	0.089	0.022	0.082	0.065	0.147
Band2-to-Band1	0.023	0.014	0.021	0.003	0.099	0.791	0.01	0.795	0.763	0.804
Band2-to-Band2	0	0	0	0	0	1	0	1	1	1
Band2-to-Band3	0.022	0.007	0.02	0.011	0.044	0.77	0.009	0.771	0.743	0.789
Band2-to-Band4	0.897	0.835	0.715	0.031	3.627	0.11	0.029	0.102	0.08	0.187
Band3-to-Band1	0.016	0.01	0.013	0.004	0.04	0.701	0.009	0.702	0.679	0.727
Band3-to-Band2	0.022	0.007	0.02	0.011	0.044	0.77	0.009	0.771	0.743	0.789
Band3-to-Band3	0	0	0	0	0	1	0	1	1	1
Band3-to-Band4	1.231	1.085	0.765	0.033	3.71	0.092	0.021	0.086	0.068	0.145
Band4-to-Band1	0.967	0.932	0.685	0.02	3.925	0.089	0.022	0.082	0.065	0.147
Band4-to-Band2	0.897	0.835	0.715	0.031	3.627	0.11	0.029	0.102	0.08	0.187
Band4-to-Band3	1.231	1.085	0.765	0.033	3.71	0.092	0.021	0.086	0.068	0.145
Band4-to-Band4	0	0	0	0	0	1	0	1	1	1

Band Co-Registration: Mean Registration Error Summary

Sub-Pixel Errors for 10 Planet Basic Images

Mean of Total Pixel Error From All Images					
BANDS		Match			
		1	2	3	4
Ref	1	0	0.0328	0.0308	0.3380
	2	0.0328	0	0.0213	0.3228
	3	0.0308	0.0213	0	0.3595
	4	0.3380	0.3228	0.3595	0

Mean of errors among Bands 1 – 3 (RGB): 0.0283 pixels

Mean of errors between Band 4 (NIR) and Bands 1 – 3 (RGB): 0.3401 pixels

NGA

Summary of Assessments

Absolute Geolocation Accuracy

- Planet accuracy specification: 10-meter RMSE → 15.2 m CE90
- Geo-registration processing: 21 December 2016 – 10 January 2017
- All images: Estimated CE90 is 15.5 meters
  - There is at least a 93.3 percent certainty that the true CE90 is less than 34.7 meters
- Excluding images of small islands: Estimated CE90 is 11.0 meters
  - There is at least a 95.9 percent certainty that the true CE90 is less than 19.0 meters

Geolocation Consistency

- Geo-registration processing: 25 August 2016 – 26 January 2017
- Planet is geo-registering PS2 images to a reference imagery layer
- Stacks of images compared over five random locations around world
- NIQU observed median errors between 0.7 to 5 pixels (2 to 17 meters), with the maximum case being 13 pixels (40 meters) assuming a typical GSD of 3.125 meters for ortho tiles
- Misalignment tolerance depends upon application

Band Co-Registration Analysis

- Geo-registration processing: 21 December 2016 – 10 January 2017
- Mean of errors among Bands 1 – 3 (RGB): 0.0283 pixels
- Mean of errors between Band 4 (NIR) and Bands 1 – 3 (RGB): 0.3401 pixels

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References

National Geospatial-Intelligence Agency, NGA.SIG.0026.04_1.0_ACCSAMP, *Accuracy and Predicted Accuracy in the NSG*: Sample Statistics*, Version 1.0 (manuscript submitted for publication in NSG Standards Registry, https://nsgreg.nga.mil/)

National Geospatial-intelligence Agency, NGA.SIG.0026.05_1.0_ACCSPEC, *Accuracy and Predicted Accuracy in the NSG: Specification and Validation*, Version 1.0 (manuscript submitted for publication in NSG Standards Registry, https://nsgreg.nga.mil/)

* National System for Geospatial-Intelligence

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